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Europäisches Patentamt  
European Patent Office  
Office européen des brevets

⑪ Publication number:

**0 208 311  
A2**

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## EUROPEAN PATENT APPLICATION

⑲ Application number: 86109400.1

⑤① Int. Cl. 4: C07C 131/04

⑳ Date of filing: 09.07.86

③① Priority: 10.07.85 IT 2151185

④③ Date of publication of application:  
14.01.87 Bulletin 87/03

⑥④ Designated Contracting States:  
AT BE DE FR GB NL SE

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⑤④ Catalytic process for preparing cyclohexanone-oxime.

⑤⑦ A catalytic process for preparing cyclohexanone-oxime by reacting cyclohexanone with  $\text{NH}_3$  and  $\text{H}_2\text{O}_2$  in the liquid phase, wherein the catalyst substantially consists of a highly crystalline substance containing  $\text{SiO}_2$  and having a zeolitic structure.

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# CATALYTIC PROCESS FOR PREPARING CYCLOHEXANONE-OXIME

DE-C-1 245 371 teaches the preparation of cyclohexanoneoxime by catalytic reaction, in the liquid phase, of cyclohexanone with ammonia and hydrogen peroxide at 5 to 40°C, in the presence of a catalyst consisting of phospho-tungstic acid or of similar compounds. A drawback of this method is, however, that this type of catalyst is difficult to handle, particularly, during the separation of the product from the catalyst.

It has now been found that it is possible to obtain the same high yields by using a completely different catalyst that is easier to handle and simplifies the process in all its steps.

Thus, the present invention relates to a catalytic process for preparing cyclohexanone-oxime by reacting cyclohexanone with  $\text{NH}_3$  and  $\text{H}_2\text{O}_2$  in the liquid phase, which process is characterized in that the catalyst substantially consists of a highly crystalline,  $\text{SiO}_2$ -containing substance having a zeolitic structure and, in particular, of a titanium-silicalite, optionally in admixture with an inert binder. Titanium-silicalites are known compounds which, for example, are described in GB-A-2 024 790 and 2 071 071.

The reaction temperature normally is in the range of from 25 to 100°C, preferably from 40 to 90°C. Tests carried out at 15°C have provided results that are not completely satisfactory.

A pressure above atmospheric pressure promotes the development of the reaction.

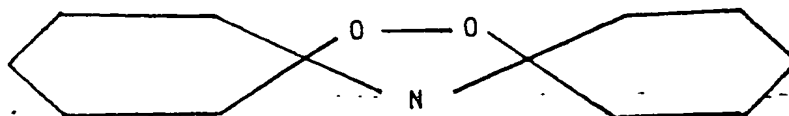
Other substances of zeolitic nature which catalyse the reaction are, first of all, the various types of silicalite, such as silicalite I (see, e.g., US-A-4 061 724), silicalite II, zirconium-silicalites and hafnium-silicalites.

Another class of analogous catalysts are the metalsilicalites, e.g., borosilicates (boralites), beryll-silicates, chromo-silicates, vanadium-silicates, zirconiumsilicates, gallium-silicates and ferro-silicates which are, in part, described in GB-A-2 024 790.

A third class of catalysts of analogous type consists of the known aluminium-silicates, generally known as "zeolites", particularly the zeolites of type Y, the zeolites ZSM5, the zeolites ZSM 11 and the other zeolites ZSM described in EP-A-129 239, 141 514 and 143 642, as well as the zeolites MB 28 described in EP-A-21 445. Some of these zeolites have already been successfully utilized in the aminoximation of cyclohexanone in the gas phase with  $\text{NH}_3$  and air.

The process according to the present invention can be carried out either continuously or discontinuously, provided that reactors with surfaces that are resistant to hydrogen peroxide are used. When the reaction is carried out in batch, it is advisable that 0.1 to 50 parts by weight (preferably from 1 to 20 parts by weight) of pure catalyst (excluding binder) for 100 parts by weight of cyclohexanone be used. If the reaction is performed in a continuous manner, it is preferred to employ a space velocity of from 0.1 to 100 kg/h of cyclohexanone - ( $\text{C}_6\text{H}_{10}\text{O}$ ) per kg of catalyst. The molar ratio of  $\text{H}_2\text{O}_2$ : $\text{C}_6\text{H}_{10}\text{O}$  is, generally, in the range of from 0.5 to 2.5 and, preferably, from 1 to 1.5, whereby  $\text{H}_2\text{O}_2$  means 100% pure hydrogen peroxide (i.e., dilution water excluded). Water ( $\text{H}_2\text{O}$ ) is the most suitable liquid vehicle for the reaction. However, it is also possible to use organic water-soluble solvents capable of dissolving both pure ammonia and its aqueous solutions such as, e.g., methanol, ethanol, propanol, isopropanol, butanol, isobutanol, tertiary butanol and mixtures thereof. Solvents with carbonyl functions such as aldehydes and ketones should be excluded.

The reaction water, which is formed according to the equation:  $\text{C}_6\text{H}_{10}\text{O} + \text{H}_2\text{O}_2 + \text{NH}_3 \rightarrow \text{C}_6\text{H}_{10}\text{NOH} + 2\text{H}_2\text{O}$  (I) gradually increases the amount of liquid vehicle as the conversion to oxime proceeds. During the reaction considerable amounts of peroxy-di-cyclohexyl-amine of the formula



(II)

are also formed.

Ammonia should always be added before the hydrogen peroxide and in excess ( $\text{NH}_3$  :  $\text{C}_6\text{H}_{10}\text{O} \geq 1$ , preferably  $\geq 1.5$  moles/mol). Otherwise, undesired side-reactions occur.

At the end of the reaction, the cyclohexanone-oxime can be separated by different methods, for example, through extraction with suitable solvents such as benzene, toluene and the cyclohexanone as used for the synthesis, whereby a hydrophobic organic phase and an aqueous phase are formed.

Cyclohexanone-oxime and unreacted cyclohexanone form the organic layer. The aqueous layer which contains the excess  $\text{NH}_3$ , as well as traces of cyclohexanone and oxime can be recycled to the reaction zone (ammoximation zone).

The following examples illustrate the invention without, however, limiting it.

#### EXAMPLE 1

A glass reactor, equipped with a stirrer and a heating jacket, was first blanketed with an inert gas (nitrogen). Subsequently, 1.5 g of a catalyst consisting of a finely ground powder of titanium-silicalite containing 3.85% by weight of highly crystalline titanium oxide (average diameter of the particles  $\leq 5 \mu\text{m}$ ) was charged. 50 cm<sup>3</sup> of a 32% by weight aqueous solution of ammonia were added to the catalyst. The mixture was stirred and 9.5 g of cyclohexanone were charged. The three-phase system (solid-aqueous-organic) formed was kept homogenous by stirring vigorously. Heating was started by conveying a liquid at 60°C into the jacket. Simultaneously, a 32% by weight aqueous solution of hydrogen peroxide was fed to the reactor by means of a metering pump. After 15 minutes, the temperature in the reactor reached 60°C while the pressure rose to a value of from 600 to 700 mm Hg above atmospheric pressure. The addition of  $\text{H}_2\text{O}_2$  was performed within 3.5 hours, during which time the pressure decreased. The temperature was maintained at 60°C and stirring was continued for a further 1.5 hours, whereafter the test was stopped and the mixture was cooled.

50 cm<sup>3</sup> of toluene were added to the resulting suspension and, after stirring for a few minutes, the aqueous phase and the organic phase were separated from the catalyst by filtration. The liquid phases were separated in a separation funnel and

the aqueous phase was extracted with two portions of toluene of 30 cm<sup>3</sup> each. The toluene solutions were combined and analysed. The analysis revealed a cyclohexanone conversion of 95% and a selectivity to cyclohexanone-oxime of 79.45%; the selectivity of hydrogen peroxide to oxime was 68.7%. At the end, about 15% of the starting cyclohexanone was found to be in the form of peroxy-dicyclohexyl-amine (see formula II above).

#### EXAMPLES 2 and 3

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Example 1 was repeated, varying temperature and pressure. The data and results given in table 1 prove that the selectivity of the conversion  $\text{H}_2\text{O}_2 \rightarrow$  oxime is very adversely affected when operating under vacuum.

#### EXAMPLE 4 (Comparative Test)

Example 1 was repeated, bringing the pressure (gauge) to zero and considerably lowering the temperature (down to 15°C). The unsatisfactory results shown in table 1 prove that it is disadvantageous to excessively reduce the thermal level of the ammoximation.

#### EXAMPLE 5

Example 1 was repeated, replacing titanium silicalite by a zirconite (zirconium-silicalite). Analogous results were obtained.

#### EXAMPLE 6

Example 1 was repeated, replacing titanium-silicalite by a boralite (boron-silicate). Analogous results were obtained.

TABLE 1 (a)

Ex.	PARAMETERS					PRODUCTS							
	C <sub>6</sub> H <sub>10</sub> O (g)	H <sub>2</sub> O <sub>2</sub> 32% b.w.	T (°C)	Time (h)	P (mmHg) (b)	Liquid phase		Gas composition		Conversion (%)		Selectivity (%)	
						aqueous (g)	organic (g)	N <sub>2</sub> O (vol.%)	O <sub>2</sub> (vol.%)	C <sub>6</sub> H <sub>10</sub> O	H <sub>2</sub> O <sub>2</sub>	C <sub>6</sub> H <sub>10</sub> O	H <sub>2</sub> O <sub>2</sub>
1	9.50	11.7	60	3 1/2	75	52.0	127	17.22	23.14	95.35	91.87	79.45	68.73
2	9.50	11.55	40	"	negative	50.8	114.5	-	-	90.37	79.20	30.97	25.74
3	9.50	11.7	25	"	0	57.0	120	0.335	95.49	82.56	98.13	20.53	15.37
4	9.55	11.8	15	3 3/4	0	71.3	91	0.094	69.07	47.79	95.48	16.70	7.22
(*)													

(\*) Comparative test.

(a) In all the tests, 50 cm<sup>3</sup> of aqueous  $NH_3$  were added and 1.5 g of Ti-silicalite were used.

(b) Above atmospheric pressure.

(c) Selectivity to oxime.

Note : Nitrogen protoxide derives from the decomposition of hydroxylamine, which forms in consequence of a parallel reaction.

## Claims

1. A catalyst process for preparing cyclohexanone-oxim by reacting cyclohexanone with ammonia and hydrogen peroxide in the liquid phase, characterized in that the catalyst substantially consists of a highly crystalline substance containing  $\text{SiO}_2$  and having a zeolitic structure.

2. The process of claim 1, wherein the catalyst is a titanium-silicalite, optionally in admixture with an inert binder.

3. The process of claim 2, wherein a zirconium-silicalite replaces, at least in part, titanium-silicalite.

4. The process of claim 2, wherein a borasilite replaces, at least in part, titanium-silicalite.

5. The process of any one of claims 1 to 4, wherein the reaction temperature ranges from 25 to 100°C.

6. The process of claim 5, wherein the reaction temperature ranges from 40 to 90°C.

7. The process of any one of claims 1 to 6, wherein the pressure is equal to or higher than atmospheric pressure.

8. The process of any one of claims 1 to 7, wherein the space velocity of cyclohexanone ranges from 0.1 to 100 kg/h per kg of pure catalyst (binder excluded).

9. The process of any one of claims 1 to 8, wherein the  $\text{H}_2\text{O}_2 : \text{C}_6\text{H}_{10}\text{O}$  molar ratio ranges from 0.5 to 2.5, whereby  $\text{H}_2\text{O}_2$  means pure hydrogen peroxide (dilution water excluded).

10. The process of any one of claims 1 to 9, wherein  $\text{NH}_3$  is added prior to  $\text{H}_2\text{O}_2$ , the  $\text{NH}_3 : \text{C}_6\text{H}_{10}\text{O}$  molar ratio being  $\geq 1$ , preferably  $\geq 1.5$ .